PAM Predicted Maintenance Interventions Module

Introduction

The Predicted Maintenance Interventions module uses the asset survival model (see *Asset Survival Models Module* in PAM Modules) to optimise the performance of each asset at the operational level by identifying assets at greatest risk of imminent failure so that they can have proactive maintenance to reduce their risks of failure rather than repaired or replaced after they fail, and also rather than on assets that are scheduled for maintenance then as specified by the manufacturers but whose risks of failure then are smaller. Thus, the module changes asset management policies from reactive fail-and-fix to proactive predict-and-prevent and so minimises the cost of operational asset management.

Risk of Asset Failure

PAM quantifies the risk of an asset failing at time *t* in three ways, as the:

- probability of the asset failing at time *t*
- probability of the asset failing at time *t* adjusted by all the costs resulting from the asset's failure (the costs of intervention and asset replacement, and the consequence costs of failure)
- probability of the asset failing at time *t* adjusted by the asset's criticality.

The probability of each asset failing at time *t* (the first item) is the output of the asset survival model, and the adjusted probabilities are calculated from it. The actual assets to have maintenance interventions at any time are worked out by considering all the risk measures, subject matter knowledge and which assets are scheduled for maintenance then.

Operational Use

The module is used operationally as follows.

1. Run the survival models to calculate each asset's risk of failure for when the next maintenance is scheduled.
2. Calculate the risk of failure scores for each asset (see above)
3. Rank the assets in descending order of each risk score to identify the assets at greatest risk of imminent failure based on each score. The actual assets to be maintained are worked out from

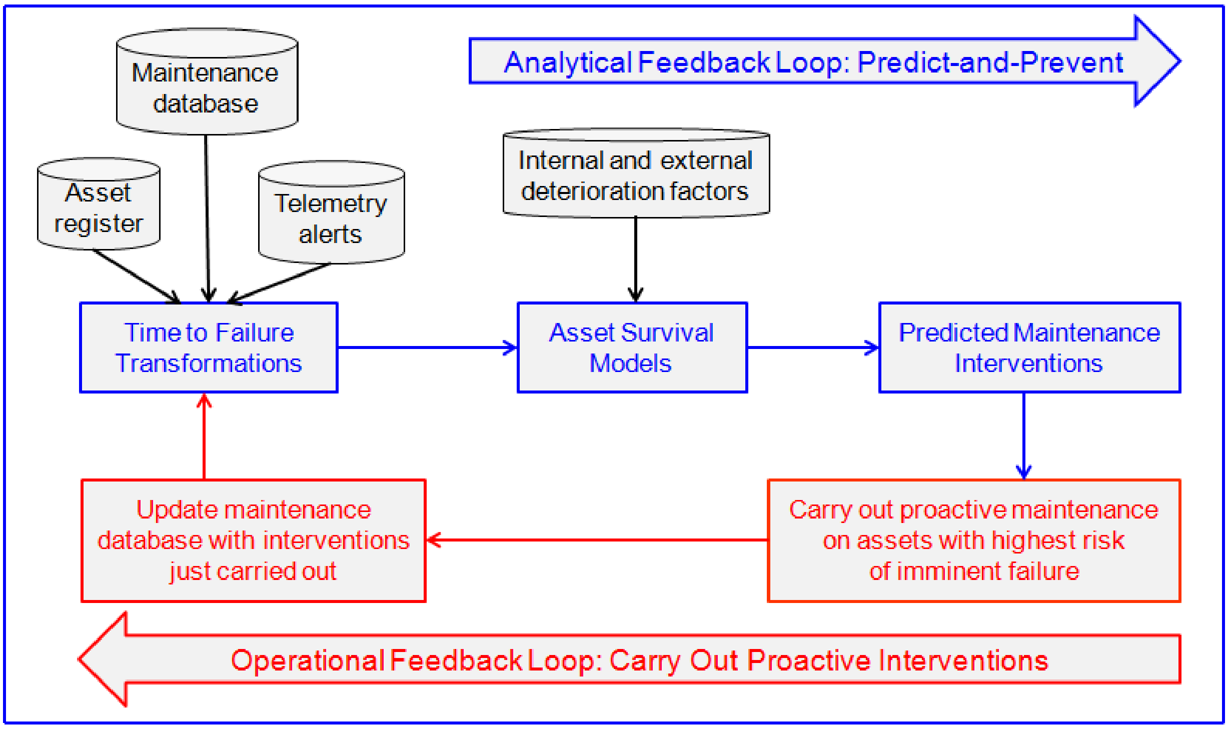
the assets' risk scores and maintenance schedules, and subject matter expertise. For example, it may be felt that an asset whose criticality based risk score is smaller than the cost based risk score of another asset requires more immediate maintenance.

4. Carry out proactive maintenance on the selected assets.
5. Update the maintenance database for the assets that had maintenance.

Schema

Figure 1 shows the schema for the module.

Figure 1



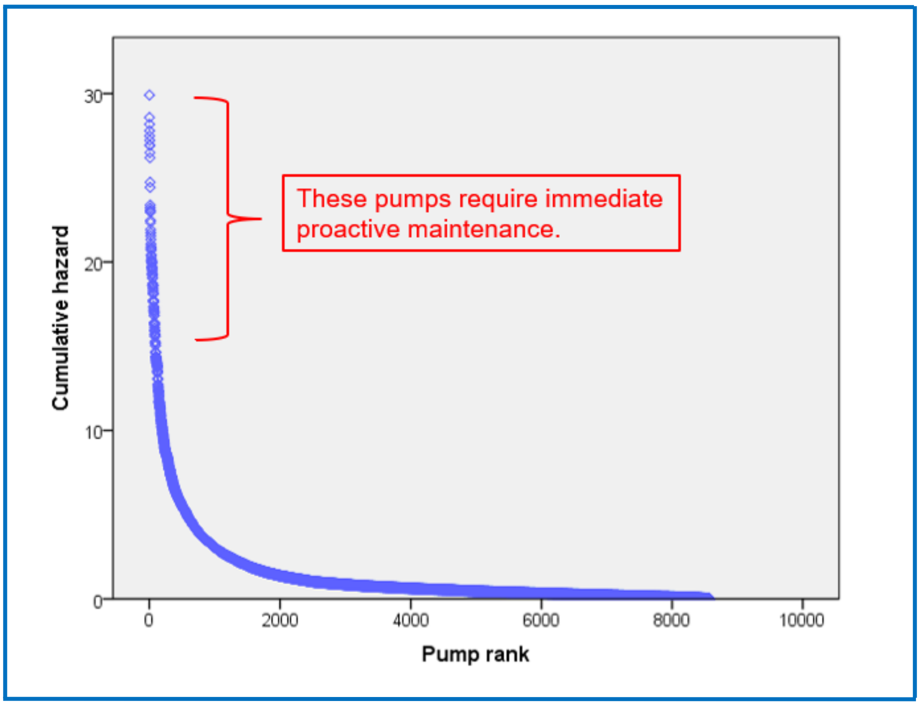
Output Files

The output of the module is graphs and tables of the assets' cumulative hazards (the cumulative risk at time *t* of asset failure) and survival probabilities when the next maintenance is scheduled for (cumulative hazard and survival probability have an inverse relationship). They are accessed from the module's visualisation component.

- If the cumulative hazard of an asset after a maintenance intervention is unchanged from before the intervention, the asset is in an ‘as bad as old’ condition after the intervention.
- If the cumulative hazard of an asset after a maintenance intervention is the same as it was when the asset was new, the asset is in an ‘as good as new’ condition after the intervention.

The data in Figure 2 and Table 1 are for 8,500 clean water and waste water pumps in 800 locations and are based on 12 years of maintenance and failure data. Figure 2 shows the distribution of the cumulative hazard when the pumps are ranked in descending order of their cumulative hazards. Pump rank 1 has the highest cumulative hazard and pump rank 8,500 has the lowest cumulative hazard. The distribution is highly skewed – a very steep decrease followed by a long tail.

Figure 2



The pumps in greatest need of immediate proactive maintenance have the largest cumulative hazards. After a pump has had a maintenance intervention, the maintenance database is updated by adding a record with the maintenance data. When the asset survival model is run with the updated database, the calculated cumulative hazard for the pump is lower and its calculated survival probability higher than they were before the maintenance. When the new cumulative hazard distribution is plotted, the pump’s much reduced need for maintenance compared to the maintenance needs of the other pumps is clear.

Table 1 summarises the cumulative hazards of the 500 pumps in greatest need of maintenance (pump ranks 1 to 500) in Figure 2. It shows that the range of the 100 largest cumulative hazards is 15.5. This is about half the range of all the cumulative hazards but is accounted for by only 1.17% of the pumps. As with Figure 2, Table 1 clearly shows the highly skewed distribution of the cumulative hazards.

Table 1

Pump Rank	Cumulative Hazard
1 – 100	14.4 – 29.9
101 – 200	10.0 – 14.3
201 – 300	7.8 – 9.9
301 – 400	6.4 – 7.7
401 – 500	5.5 – 6.3

Figure 3 shows how proactive maintenance and reactive maintenance reduce the cumulative hazard (the data are for one pump in a waste water pumping station). From left to right, the interventions are repair, repair, refurbish, reset, adjust, lubricate. Since the pump was in a bad state initially, it failed and required reactive maintenance. This reduced the cumulative hazard, and proactive maintenance was then required to reduce the cumulative hazard further to a sustainable low level. The effects of the different types of maintenance on reducing the pump's cumulative hazard are clear.

Figure 3